

Sputtering From Io's Volcanic Atmosphere: The Source Of Jupiter's Magnetosphere

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We have developed a model for the sputtering processes from a volcanic atmosphere. We calculate the altitude of the exobase as a function of latitude and longitude using our numerical gas dynamic simulations of a volcanic atmosphere on Io. The simulation results are consistent with recent millimeter-wave observations of SO₂ which show that Io's atmosphere has a temperature of about 500 K at 40 km of altitude while the surface has a maximum temperature of 130 K due to solar irradiation. In our simulations we include a relatively small surface hot spot around the vent and find that infrared radiation from such a hot spot is capable of warming up the atmosphere to high temperatures when we take into account the greenhouse effect produced by volcanic aerosols. Corotating ions with a density of $2 \times 10^3 \text{ cm}^{-3}$ impact on the volcanic atmosphere producing sputtered neutral SO₂ molecules, with a yield of 23 molecules per incident ion. These molecules are injected into the hot plasma torus, dissociated and ionized by electron impact and charge exchange. Knowledge of the location of the exobase of the volcanic atmosphere allows us to develop a collision cascade sputtering model of the form:

$$N = \int_0^\infty \int_0^A F(E) dE dA = \int_0^\infty \int_0^A \frac{C}{[E+U]^2} \left[1 - \left(\frac{E_1}{E+U} \right)^{1/2} \right] dE dA$$

where N is the number of particles sputtered per second, E the energy of the sputtered molecule at the exobase, F(E) the flux of particles in the energy interval E to E+dE, C a constant, and E₁ the energy of the incident ion. The gravitational escape energy is a function of exobase height, $U = -K/r$, where K is a constant and r is the distance from the center of Io. dA is an element of the surface area normal to the direction of impact of an incident ion with the exobase. We find a source rate consistent with our own studies as well as other independent studies of torus plasma processes based on Voyager, IUE and ground observations.

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